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## Pressure Wave Dosimetry for “Retinal Ganglion Cell Damage in an Experimental Rodent Model of Blast-Mediated Traumatic Brain Injury”

Recently, Mohan et al.<sup>1</sup> reported a study of blast effects on the retina and optic nerve, using a small, custom built, enclosed “blast chamber.” This chamber was 50 cm long and 33 cm wide. Two parts of this chamber were separated by a Mylar membrane. The side of the chamber away from the test subject was pressurized until the Mylar membrane burst, thereby reportedly generating a blast wave.

The only pressure measurement reported by Mohan et al.<sup>1</sup> was the pressure of the pressurized side at which the Mylar membrane burst ( $20 \pm 0.2$  pounds per square inch [psi];  $137.8 \pm 1.3$  kilopascals [kPa]). However, this is insufficient information to characterize the pressure/shock wave experienced by the mouse subjects. Was a pressure transducer of sufficient bandwidth placed near the target position of the blast (exposure) side of the chamber to directly measure the magnitude and shape of the overpressure wave generated in this chamber? To properly characterize overpressure loading conditions and enable comparison of results between studies, it is important to report conditions at or near the test subject. Various studies have used a variety of methods to generate blast loads, including shock tubes, air guns, and live explosives. To translate blast wave exposures produced by explosives into experimental methodologies appropriate for the laboratory and to develop computer simulations of the blast exposure, a complete pressure time history is necessary.

The mouse subject was described as being located at a distance of 30 cm from the Mylar burst membrane. However, the illustration in Figure 1B<sup>1</sup> seems to indicate a much closer distance. The test setup as described may have generated a reasonable blast exposure environment, but without a pressure time history, complications may have occurred that cannot be dismissed, as follows:

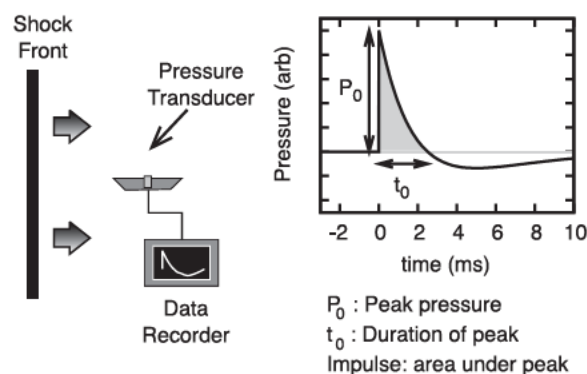
- Exposure to non Friedlander style blast wave: if the subject is too close to the membrane, the blast wave is unable to form following the turbulence introduced by the fracturing of the Mylar membrane.
- Exposure to reflections: any object present in the blast field, including the walls of the chamber, will reflect the blast wave. These reflections will return and strike the subject, causing potentially significant elevated impulse exposure. The mounting apparatus can also reflect the blast wave, causing the off side eye to experience direct blast exposure rather than indirect exposure. This cannot be ascertained from the diagram provided; a photo of the set up would have provided necessary perspective.
- Duration of exposure: blast wave duration can range from a few hundred microseconds to  $\geq 10$  ms. Because the membrane area is much smaller than the diameter of the test chamber, as the blast wave expands to fill the chamber, it will reduce the positive phase duration. The duration must be sufficient to be operationally relevant (more than 100  $\mu$ s) but not so excessive that the “effective load,” when scaled to human equivalency, becomes equivalent to nuclear blasts ( $\geq 3$  ms to the mouse<sup>2</sup>).

- Acceleration: relatively (in terms of test subject size) large blast loads can induce significant accelerative movement in small test subjects such as mice.<sup>3</sup> This can introduce confounding injuries. If the mouse head is secured, this is under control, but the method description did not discuss this. An estimate of potential motion can be made given the pressure loading to the subject, but this also was not provided.

It is not clear from the illustration of the blast chamber in Figure 1 of the study<sup>1</sup> if there was any damping mechanism or pressure relief mechanism to prevent the pressure waves from reflecting off of the walls of the chamber and returning to the target location. If this was so, the mouse subjects likely experienced a very complex, turbulent exposure to multiple blast waves, complicating the interpretation of the study's results. Once again, direct measurement of the pressure wave at the target position would have answered this concern.

A free field blast wave<sup>4</sup> generated by an explosive event generally has the form shown in Figure 1. This figure shows an idealized measurement of the overpressure by a pressure transducer located at a fixed distance from the blast source. The pressure shows a nearly instantaneous increase to a peak positive pressure value (the shock), followed by a rapid decay back to the ambient pressure. The duration of this positive peak is on the order of a few milliseconds or less. Following the positive pressure peak, there is a negative pressure trough, in which the pressure is less than the ambient pressure.

To facilitate comparisons between studies, a standardized characterization of the blast wave is necessary. A graph showing a typical pressure wave profile should always be presented. Furthermore, for blast waves of the form shown in Figure 1 it is recommended that the following parameters be reported:



**FIGURE 1.** A shock wave is characterized by a nearly instantaneous rise in pressure, followed by a rapid decrease to a value that is below that of the surrounding ambient pressure, resulting in a region of negative pressure behind the shock front. Pertinent parameters are the peak pressure ( $P_0$ ) and the duration of the positive pressure peak ( $t_0$ ). The impulse, which is the time integral of the positive pressure peak, is a measure of the load on the target. In the arrangement shown at the left, the pressure sensor is perpendicular to the direction of travel of the shock wave. This results in a measure of the static pressure, or overpressure of the shock wave. Overpressure results in a crushing force applied to the target. Had the detector faced into the oncoming shock wave, reflected pressure would have been measured.

- a) Peak positive pressure,  $P$  (in units of kPa)
- b) Duration of the positive pressure peak (in ms)
- c) Precise location of the pressure transducer in terms of both the source (membrane) and test subject

If the pressure profile is not that typical of a shock wave, then in addition to the peak positive pressure and duration of the positive pressure, the impulse (in kPa ms) should be reported.

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The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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